

## TITLE OF THE INVENTION

Plating Apparatus and Method

## BACKGROUND OF THE INVENTION

## 5 Field of the Invention

The present invention relates to a plating apparatus and method, and more particularly to an electrolytic type plating apparatus and method for carrying out plating while applying a voltage to a substrate to be treated which is immersed in a treating solution.

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## Description of the Background Art

For a plating apparatus for forming a plated film such as Cu (copper) on a substrate to be treated such as a silicon wafer, conventionally, there has been known a plating apparatus using a face down method in which a plating solution is filled in a plating solution vessel having an anode electrode provided in a bottom part, the substrate is turned downward with respect to a plating solution level and is immersed in the plating solution, and a voltage is applied between the substrate and the anode electrode in the same state (for example, see the patent document 1).

In the conventional plating apparatus, a cathode electrode is caused to come in contact with a peripheral edge portion of the substrate, and a voltage is applied through the cathode electrode to the substrate and a surface of the substrate (hereinafter referred to as a surface to be plated) on the opposite side of the anode electrode is caused to function as the cathode electrode.

It is important that a plated film having a uniform thickness should be formed in the surface to be plated. The reason is that if a plated film having a nonuniform

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thickness is formed in the surface to be plated as a result of execution of plating, there is a possibility that various drawbacks might be caused.

[Patent Document 1]

Japanese Patent Application Laid-Open No. 2001 - 316885 (Fig. 17)

5 In the conventional plating apparatus, however, it is impossible to form a plated film having a uniform thickness in a substrate to be treated. The reason is as follows.

The plating apparatus using a face down method has such a structure that a cathode electrode is caused to come in contact with a peripheral edge portion of a substrate to be treated and a voltage is thus applied. In the substrate, therefore, the  
10 voltage is raised in the vicinity of the peripheral edge portion which is close to the cathode electrode, and is greatly dropped from the cathode electrode toward a central portion.

Accordingly, a plating speed tends to be more increased in the peripheral edge portion than that in the central portion of the substrate. A thickness of a plated film is  
15 reduced in the vicinity of the center of the substrate and is gradually increased toward the peripheral edge portion of the substrate. For this reason, a plated film having a nonuniform thickness is finally formed in the surface to be plated in the substrate.

Furthermore, when a diameter of a wafer is increased to 300 mm which has recently been started to be applied, a distance between the peripheral edge portion and the  
20 central portion in the substrate is more increased. Consequently, a difference in an electric potential in the surface of the substrate is more increased so that the nonuniformity of the thickness of the film tends to be further deteriorated.

Accordingly, it is an important development item of a plating process to suppress the difference in an electric potential in the surface of the substrate and to  
25 improve the nonuniformity of the thickness of the film.

## SUMMARY OF THE INVENTION

It is an object of the present invention to provide a plating apparatus and method capable of forming a plated film having a uniform thickness in a substrate to be treated.

5           A first aspect of the present invention is directed to a plating apparatus including a plating solution vessel, an anode electrode, holding means, a cathode electrode and an anode electrode moving device. The plating solution vessel is filled with a plating solution. The anode electrode is provided in the plating solution vessel. The holding means serves to hold a substrate to be treated and to immerse the substrate in  
10 the plating solution during plating. The cathode electrode is provided in a contact portion of the holding means with the substrate and serves to apply a voltage to the substrate. The anode electrode moving device serves to drive the anode electrode corresponding to a plating situation of the substrate.

The anode electrode can be caused to approach the cathode electrode side by  
15 the anode electrode moving device as plating progresses. Thus, it is possible to form a uniform plated film throughout the plating.

A second aspect of the present invention is directed to a plating apparatus including a plating solution vessel, an anode electrode, holding means, a cathode electrode and a holding means moving device. The plating solution vessel is filled with  
20 a plating solution. The anode electrode is provided in the plating solution vessel. The holding means serves to hold a substrate to be treated and to immerse the substrate in the plating solution during plating. The cathode electrode is provided in a contact portion of the holding means with the substrate and serves to apply a voltage to the substrate. The holding means moving device serves to drive the holding means corresponding to a  
25 plating situation of the substrate.

The substrate can be caused to approach the anode electrode side by the holding means moving device as the plating progresses. Thus, it is possible to form a uniform plated film throughout the plating.

A third aspect of the present invention is directed to a plating apparatus  
5 including a plating solution vessel, an anode electrode, holding means, a cathode electrode, a jet nozzle, a rectifying plate and a rectifying plate moving device. The plating solution vessel is filled with a plating solution. The anode electrode is provided in the plating solution vessel. The holding means serves to hold a substrate to be treated and to immerse the substrate in the plating solution during plating. The cathode  
10 electrode is provided in a contact portion of the holding means with the substrate and serves to apply a voltage to the substrate. The jet nozzle serves to blow off the plating solution upward from a lower part of the plating solution vessel. The rectifying plate serves to control a solution flow of the jet nozzle. The rectifying plate moving device serves to drive the rectifying plate corresponding to a plating situation of the substrate.

15 The rectifying plate is moved in accordance with an instruction of the rectifying plate moving device as the plating progresses. Consequently, a solution flow blown up from the jet nozzle can be always controlled. Thus, it is possible to form a uniform plated film throughout the plating.

A fourth aspect of the present invention is directed to a plating apparatus  
20 including a plating solution vessel, an anode electrode, holding means, a cathode electrode, a jet nozzle, an insert ring and an insert ring inside diameter changing device. The plating solution vessel is filled with a plating solution. The anode electrode is provided in the plating solution vessel. The holding means serves to hold a substrate to be treated and to immerse the substrate in the plating solution during plating. The  
25 cathode electrode is provided in a contact portion of the holding means with the substrate

and serves to apply a voltage to the substrate. The jet nozzle serves to blow off the plating solution upward from a lower part of the plating solution vessel. The insert ring serves to control the plating solution blown off through the jet nozzle in the vicinity of a surface of the substrate. The insert ring inside diameter changing device serves to  
5 change an inside diameter of the insert ring corresponding to a plating situation of the substrate.

The inside diameter of the insert ring is changed in accordance with an instruction of the insert ring inside diameter changing device as the plating progresses. Consequently, a solution flow blown up from the jet nozzle can be always controlled.  
10 Thus, it is possible to form a uniform plated film throughout the plating.

A fifth aspect of the present invention is directed to a plating apparatus including a plating solution vessel, an anode electrode, holding means and a cathode electrode. The plating solution vessel is filled with a plating solution. The anode electrode is provided in the plating solution vessel. The holding means serves to hold a  
15 substrate to be treated and to immerse the substrate in the plating solution during plating. The cathode electrode is provided in a contact portion of the holding means with the substrate and serves to apply a voltage to the substrate, the cathode electrode being provided in contact with the substrate in a peripheral edge portion and an inner portion of the substrate corresponding to a chip pattern formed on the substrate.

20 By applying a voltage to the substrate by the cathode electrode, it is possible to control a difference in an electric potential between a peripheral portion and an inner portion in the substrate and to maintain a uniform current distribution. Accordingly, it is possible to form a uniform plated film in the substrate.

A sixth aspect of the present invention is directed to a plating method of  
25 opposing an anode electrode to a substrate to be treated which is provided in contact with

a cathode electrode in a plating solution vessel filled with a plating solution, and applying a voltage between the anode electrode and the cathode electrode, thereby plating the substrate, including a step (a). At the step (a), a spacing between the anode electrode and the substrate which are opposed to each other is changed corresponding to a plating  
5 situation of the substrate.

The anode electrode can be caused to approach the cathode electrode side as the plating progresses. Thus, it is possible to form a uniform plated film throughout the plating.

These and other objects, features, aspects and advantages of the present  
10 invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic view showing a structure of a plating apparatus according  
15 to a first embodiment,

Fig. 2 is a schematic view showing a state of the plating apparatus according to the first embodiment at an early stage of plating,

Fig. 3 is a circuit diagram showing each resistance between an anode electrode and a cathode electrode,

20 Fig. 4 is a view showing a state in which a position of the anode electrode is changed as plating progresses,

Fig. 5 is a schematic view showing a state of a plating apparatus according to a second embodiment at the early stage of the plating,

Fig. 6 is a view showing a state in which a position of holding means is changed  
25 as the plating progresses,

Fig. 7 is a schematic view showing a state of a plating apparatus according to a third embodiment at the early stage of the plating,

Fig. 8 is a view showing a state in which a position of a rectifying plate is changed as the plating progresses,

5 Fig. 9 is a schematic view showing a structure of a plating apparatus according to a fourth embodiment,

Fig. 10 is a view showing a contact position with a cathode electrode in a substrate to be treated according to a conventional art, and

10 Fig. 11 is a view showing a contact position with a cathode electrode provided in a plating apparatus according to a fifth embodiment.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will be specifically described below with reference to the drawings showing preferred embodiments.

15 <First Embodiment>

Fig. 1 is a schematic view showing a structure of a plating apparatus according to the present embodiment.

20 In Fig. 1, a substrate 1 to be treated is held by holding means 2 such that a surface 1a to be plated in the substrate 1 is opposed to a plating solution level 4 filled in a plating solution vessel 3. The substrate 1 has a peripheral edge portion held by the holding means 2, and a cathode electrode 5 is provided in a contact portion of the substrate 1 and the holding means 2.

Moreover, an anode electrode 6 taking such a shape that a thickness of a central portion is greater than that of a peripheral edge portion is provided in the plating solution  
25 vessel 3. Moreover, a supply port 7 for supplying a plating solution is provided in a

bottom portion 3a of the plating solution vessel 3, and furthermore, a jet nozzle 8 is provided to penetrate through the anode electrode 6 and a filter 9 from the bottom portion 3a of the plating solution vessel 3.

The jet nozzle 8 blows off the plating solution supplied through the supply port  
5 7 from the bottom portion 3a of the plating solution vessel 3 toward the plating solution level 4, thereby generating an overflow circulation of the plating solution.

Moreover, the filter 9 prevents anode slime (copper particles in case of copper plating) generated on a surface of the anode electrode 6 and a decomposition by-product of an additive and a foreign substance which are generated in the vicinity of the anode  
10 electrode 6 from entering the vicinity of the substrate 1 in such a manner that they do not influence a plating reaction or stick onto the surface 1a of the substrate 1 during plating.

Furthermore, a rectifying plate 10 is provided above the filter 9 of the plating solution vessel 3, and the plating solution blown off through the jet nozzle 8 passes through the rectifying plate 10, thereby controlling a flow of the plating solution.

15 In order to carry out the plating, the holding means 2 is moved toward the plating solution level 4 and the substrate 1 is immersed in the plating solution of the plating solution vessel 3 in such a condition that the substrate 1 is held. Such a state is shown in Fig. 2.

In the immersion state, an insert ring 11 is provided on the plating solution level  
20 4 side of the cathode electrode 5 disposed on the holding means 2 in order to control the flow of the plating solution blown off through the jet nozzle 8 in the vicinity of the surface 1a of the substrate 1 during the plating.

Moreover, an outer vessel 12 is provided on the outside of the plating solution vessel 3 and serves to collect the plating solution overflowing due to the overflow  
25 circulation of the plating solution. The plating solution thus collected is cleaned by a



circulation path which is not shown and is then supplied from the supply port 7 again.

Furthermore, the plating apparatus according to the present embodiment is provided with an anode electrode moving device 13 capable of moving a position of the anode electrode 6 in a vertical direction, that is, a direction of a depth of the plating solution.

In the case in which the plating is to be carried out by using the plating apparatus, the substrate 1 held by the holding means 2 is first immersed in the plating solution in the plating solution vessel 3 as shown in Fig. 2. Next, the holding means 2 is rotated in the immersion state in such a manner that a rotating axis is set into a direction of a normal of the plating solution level 4.

Subsequently, a voltage is applied between the cathode electrode 5 and the anode electrode 6 so that the surface 1a of the substrate 1 is started to be plated.

The cathode electrode 5 is provided in contact with the surface 1a in the peripheral edge portion of the substrate 1. As is indicated to be the problem of the conventional art, therefore, a voltage is raised in the vicinity of the peripheral edge portion which is close to the cathode electrode 5 and is gradually dropped from the cathode electrode 5 toward the central portion.

However, the plating apparatus according to the present embodiment employs the anode electrode 6 taking such a shape that the thickness of the central portion is greater than that of the peripheral edge portion. Therefore, a distance between the central portion of the substrate 1 and the anode electrode 6 is smaller than that between the peripheral edge portion of the substrate 1 and the anode electrode 6. Consequently, a resistance value of the plating solution between the central portion of the substrate 1 and the anode electrode 6 is relatively smaller than that of the plating solution between the peripheral edge portion of the substrate 1 and the anode electrode 6.

Accordingly, the shape of the anode electrode 6 is preset such that a balance between the difference in an electric potential and the difference in a resistance can be taken, that is, the difference in an electric potential is offset by the difference in a resistance. At the early stage of the plating, consequently, a uniform plated film is  
 5 formed in the surface 1a of the substrate 1.

As shown in Fig. 3, it is assumed that a resistance value of the plating solution between the peripheral edge portion of the substrate 1 provided in contact with the cathode electrode 5 and the anode electrode 6 is represented by  $R1e$ , the resistance value of the plating solution between the central portion of the substrate 1 and the anode  
 10 electrode 6 is represented by  $R1c$ , a resistance value of a seed film formed on the surface 1a of the substrate 1 between the peripheral edge portion and the central portion in the substrate 1 is represented by  $R_s$  and a current is set to flow in the central portion of the substrate 1 more easily by  $(1 + k)$  times as much as a current flow in the peripheral edge portion by the insert ring 11 and the rectifying plate 10 at an early stage (initialization of  
 15 the insert ring 11 or the like will be hereinafter referred to as hardware setting). In this case, the thickness of the anode electrode 6 is set such that the resistance value  $R1e$  and the resistance value  $R1c$  have the following relationship at the early stage of the plating.

$$V(1 + k) / (R1c + R_s) = V / R1e \quad (1)$$

The equation (1) has a left member indicating a value of a current flowing in the central  
 20 portion of the substrate 1 and a right member indicating a value of a current flowing in the peripheral edge portion of the substrate 1.  $V$  represents a difference in an electric potential between the anode electrode 6 and the cathode electrode 5.

Consequently, the following equation can be obtained from the equation (1).

$$R1c = R1e(1 + k) - R_s \quad (2)$$

25 In order to set up the relationship of the equation (2), accordingly, the thickness

of the anode electrode 6 is determined in such a manner that the distance between the central portion of the substrate 1 and the anode electrode 6 is shorter than the distance between the peripheral edge portion of the substrate 1 and the anode electrode 6.

The resistance value  $R_s$  is usually increased continuously from the peripheral edge portion toward the central portion in the substrate 1. Based on the equation (2), therefore, the thickness of the anode electrode 6 is smoothly increased from the peripheral edge portion toward the central portion in the anode electrode 6.

Returning to the plating, a uniform plated film is formed in the surface 1a at the early stage. When the plating progresses, the resistance value  $R_s$  for the substrate 1 is gradually decreased. For this reason, the equation (2) is unbalanced as the plating progresses. Thus, a film forming speed of the plating is more increased in the central portion of the substrate 1. In other words, a current distribution of the plating solution on the substrate 1 becomes high in the central portion so that the plated film is formed more thickly in the central portion than that in other portions.

Accordingly, it is necessary to control the current distribution to be high for the portion of the substrate in which the plated film tends to be formed thinly and to control the current distribution to be low for a portion of the substrate in which the plated film tends to be formed thickly.

The plating apparatus according to the present embodiment is provided with the anode electrode moving device 13 for moving the anode electrode 6 from the bottom portion 3a of the plating solution vessel 3 toward the plated surface 4.

In other words, the resistance value  $R_s$  is decreased as the formation of the plated film progresses. Therefore, it is necessary to drive the anode electrode 6 by the anode electrode moving device 13, thereby shortening the distance between the anode electrode 6 and the substrate 1 corresponding to the decrease in the resistance value  $R_s$ .

This is apparent from the equation (2).

More specifically, the equation (2) can be expressed in the following manner, wherein the distance between the peripheral edge portion of the substrate 1 and the anode electrode 6 is represented by  $L$ , a difference in a thickness between the central portion and the peripheral edge portion in the anode electrode 6 is set to be  $m$ , a constant related to an electric resistivity of the plated film is represented by  $\rho_1$ , and a constant related to an electric resistivity of the plating solution is represented by  $\rho_2$ .

$$\rho_2 (L - m) = \rho_2 L (1 + k) - \rho_1 / d \quad (3)$$

wherein  $d$  represents a thickness of a plated film (a seed film thickness + a thickness of a plated film formed by the plating). From the equation (3), the following relationship can be obtained for the distance  $L$  between the peripheral edge portion of the substrate 1 and the anode electrode 6.

$$L = \alpha / d - \beta \quad (4)$$

wherein  $\alpha$  represents a constant  $\rho_1 / k \rho_2$  and  $\beta$  represents a constant  $m / k$ .

As is apparent from the equation (4), the distanced  $L$  is reduced when the thickness  $d$  of the plated film is increased. As shown in Fig. 4, accordingly, moving control is carried out in such a manner that the distance  $L$  is shortened to set up the relationship of the equation (4), that is, the anode electrode 6 is caused to approach the untreated substrate 1 by means of the anode electrode moving device 13 when the plating progresses.

The thickness  $d$  of the plated film can be obtained in the following manner, for example.

As an example, it is supposed that copper plating is carried out within a range of 190 mm or less in diameter in the disk-shaped substrate 1 having a diameter of 200 mm.

In this case, an electric charge amount of 765.7 C is required for forming a copper plated

film in a thickness of  $1.0 \mu\text{m}$  in the substrate 1 by the Faraday's electrolysis law. This is derived from:

$$1.0 \mu\text{m} \times (\pi \times 95^2 \text{ mm}^2) \times 8.9 \text{ g} / \text{cm}^3 \times 96500 \text{ C} / \text{mol} \times 2 / 63.57 \text{ g} / \text{mol} = 756.7 \text{ C}.$$

- 5  $\pi \times 95^2 \text{ mm}^2$  indicates an area of the plated surface 1a of the substrate 1,  $8.9 \text{ g} / \text{cm}^3$  indicates a specific gravity of copper,  $96500 \text{ C} / \text{mol}$  indicates a Faraday constant, 2 indicates the number of electrons required for a film forming reaction with respect to one atom of copper, and  $63.57 \text{ g} / \text{mol}$  indicates an atomic weight of the copper.

- Accordingly, a cumulative charge amount is obtained by observing a current  
10 value during the plating and a time required for the flow of the current value. The cumulative charge amount is divided by 756.7C so that a thickness d' of the copper plated film thus formed is calculated. Therefore, the total thickness d is obtained by adding the thickness of the seed film to the thickness d'.

- Thus, it is possible to form a plated film having a uniform thickness in the  
15 substrate 1 throughout the plating as well as the early stage of the plating by moving the anode electrode 6 in such a direction as to approach the substrate 1 by the anode electrode moving device 13 in accordance with the equation (4) based on the obtained thickness d.

- While the anode electrode 6 taking such a shape that the thickness of the central portion is greater than that of the peripheral edge portion has been employed in the  
20 description of the present embodiment, the anode electrode 6 may be a flat plate. In this case, hardware setting is carried out such that "k" of the equation (2) has the following value at the early stage.

$$k = R_s / R_{1e} \quad (5)$$

- When the plating progresses, the anode electrode 6 is moved by the anode  
25 electrode moving device 13 based on the relationship of the following equation (6)

derived from the equation (5). In the same manner as described above, consequently, a plated film having a uniform thickness can be formed in the substrate 1.

$$L = \alpha / d \quad (6)$$

By employing the anode electrode 6 taking such a shape that the thickness of the central portion is greater than that of the peripheral edge portion, it is possible to increase the degree of freedom of the hardware setting. Consequently, it is possible to carry out the hard setting more delicately in order to form a uniform plated film.

#### <Second Embodiment>

A plating apparatus according to the present embodiment is provided with a holding means moving device for vertically moving holding means holding a substrate to be treated corresponding to a plating situation.

As described in the first embodiment, the resistance value  $R_s$  for the substrate 1 is decreased as the plating progresses. Consequently, initial hardware setting becomes unbalanced as the plating progresses. Thus, a current distribution on the substrate 1 is changed so that a plated film having a nonuniform thickness is finally formed.

Accordingly, it is necessary to control the current distribution to be high for the portion of the substrate in which the plated film tends to be formed thinly and to control the current distribution to be low for a portion of the substrate in which the plated film tends to be formed thickly.

While the anode electrode moving device 13 for moving the anode electrode 6 is provided in the first embodiment, a holding means moving device 21 for vertically moving holding means 2 holding the substrate 1 is provided in the present embodiment as shown in Fig. 5. Since other structures are the same as those in the first embodiment, description will be omitted.

In the plating apparatus according to the present embodiment, a current value

during plating and a time required for a flow of the current value are observed to obtain a thickness  $d'$  of the plated film in the same manner as in the first embodiment. Based on a thickness  $d$  obtained by adding the thickness  $d'$  to a thickness of a seed film and the equation (4), accordingly, the holding means 2 is moved by the holding means moving device 21 in such a manner that the substrate 1 approaches an anode electrode 6 as the plating progresses from a state shown in Fig. 5 to a state shown in Fig. 6. In the same manner as in the first embodiment, consequently, it is possible to form a plated film having a uniform thickness in the substrate 1 throughout the plating as well as an early stage of the plating.

While the anode electrode 6 taking such a shape that a thickness of a central portion is greater than that of a peripheral edge portion has also been employed in the present embodiment, it is apparent that the anode electrode 6 may be a flat plate.

#### <Third Embodiment>

A plating apparatus according to the present embodiment is provided with a rectifying plate moving device for vertically moving a rectifying plate to control a plating solution flow corresponding to a plating situation.

As described in the first embodiment, the resistance value  $R_s$  for the substrate 1 is decreased as the plating progresses. Consequently, initial hardware setting becomes unbalanced as the plating progresses. Thus, a current distribution on the substrate 1 is changed so that a plated film having a nonuniform thickness is finally formed.

Accordingly, it is necessary to control the current distribution to be high for the portion of the substrate in which the plated film tends to be formed thinly and to control the current distribution to be low for a portion of the substrate in which the plated film tends to be formed thickly.

As shown in Fig. 7, in the present embodiment, there is provided a rectifying

plate moving device 31 for vertically moving a rectifying plate 10 to control a plating solution flow. Since other structures are the same as those in the first embodiment, description will be omitted.

At an early stage of plating, the rectifying plate 10 is provided close to the  
5 substrate 1 as shown in Fig. 7 in order to offset the great resistance value  $R_s$  of the substrate 1 between a peripheral edge portion and a central portion in the substrate 1. Consequently, the plating solution jetted from a jet nozzle 8 concentrates in the central portion of the substrate 1. Therefore, it is possible to form a uniform plated film at the early stage of the plating.

10 However, the resistance value  $R_s$  is decreased as the plating progresses. For this reason, it is necessary to correspondingly change the flow of the plating solution.

In the plating apparatus according to the present embodiment, as shown in Fig. 8, the rectifying plate 10 is moved downward by the rectifying plate moving device 31 in such a manner that a spacing between the rectifying plate 10 and the substrate 1 is  
15 increased as the plating progresses.

When the spacing between the rectifying plate 10 and the substrate 1 is increased, the plating solution evenly flows to a surface 1a to be plated in the substrate 1 by a rectifying function of the rectifying plate 10. Consequently, the flow causing the plating solution to concentrate in the central portion of the substrate 1 at the early stage of  
20 the plating can be diffused to the whole surface 1a of the substrate 1 as the plating progresses.

In the plating apparatus according to the present embodiment, thus, the rectifying plate 10 is set to cause the plating solution flow to concentrate in the central portion of the substrate 1 at the early stage of the plating in which a film forming speed in  
25 the peripheral edge portion of the substrate 1 tends to be increased, and is moved



downward by the rectifying plate moving device 31 in such a manner that the plating solution flows evenly to the surface 1a as the plating progresses. In the same manner as in the first embodiment, consequently, it is possible to form a plated film having a uniform thickness in the substrate 1 throughout the plating as well as the early stage of the plating.

While an anode electrode 6 taking such a shape that a thickness of a central portion is greater than that of a peripheral edge portion has also been employed in the present embodiment, it is apparent that the anode electrode 6 may be a flat plate.

#### <Fourth Embodiment>

A plating apparatus according to the present embodiment is provided with an insert ring inside diameter changing device for changing an inside diameter of an insert ring controlling a plating solution flow in the vicinity of a substrate to be treated corresponding to a plating situation.

As described in the first embodiment, the resistance value  $R_s$  for the substrate 1 is decreased as the plating progresses. Consequently, initial hardware setting becomes unbalanced as the plating progresses. Thus, a current distribution on the substrate 1 is changed so that a plated film having a nonuniform thickness is finally formed.

Accordingly, it is necessary to control the current distribution to be high for the portion of the substrate in which the plated film tends to be formed thinly and to control the current distribution to be low for a portion of the substrate in which the plated film tends to be formed thickly.

As shown in Fig. 9, in the present embodiment, there is provided an insert ring inside diameter changing device 41 for changing an inside diameter of an insert ring 11 controlling a plating solution flow. Since other structures are the same as those in the first embodiment, description will be omitted.

In the case in which the inside diameter of the insert ring 11 is increased, a thickness of the plated film in a central portion of the substrate 1 tends to be reduced.

At an early stage of the plating, the inside diameter of the insert ring 11 is reduced in order to offset the great resistance value  $R_s$  of the substrate 1 between a peripheral edge portion and the central portion in the substrate 1. Consequently, it is possible to form a uniform plated film at the early stage of the plating.

However, the resistance value  $R_s$  is decreased as the plating progresses. For this reason, it is necessary to correspondingly change the plating solution flow.

In the plating apparatus according to the present embodiment, the inside diameter of the insert ring 11 is increased by the insert ring inside diameter changing device 41 as the plating progresses.

In the plating apparatus according to the present embodiment, thus, the inside diameter of the insert ring 11 is increased by the insert ring inside diameter changing device 41 corresponding to the plating situation. In the same manner as in the first embodiment, consequently, it is possible to form a plated film having a uniform thickness in the substrate 1 throughout the plating as well as the early stage of the plating.

While an anode electrode 6 taking such a shape that a thickness of a central portion is greater than that of a peripheral edge portion has also been employed in the present embodiment, it is apparent that the anode electrode 6 may be a flat plate.

<Fifth Embodiment>

In a plating apparatus according to the present embodiment, a cathode electrode taking such a shape as to come in contact in a peripheral edge portion and an inner portion of a substrate to be treated corresponding to a chip pattern formed on the substrate is used as a cathode electrode for applying a voltage to the substrate.

As shown in Fig. 10, conventionally, a contact portion 50 with the cathode

electrode is taken to be scattered along the peripheral edge portion of the substrate 1.

In the present embodiment, however, a cathode electrode having such a shape as to correspond to a chip pattern formed on the substrate 1 is prepared to take contact portions 50 and 51 with the cathode electrode also on a boundary of a chip having no pattern, for example, in addition to the peripheral edge portion of the substrate 1 as shown in Fig. 11. The substrate 1 and the cathode electrode make a wet contact in a plating solution.

Consequently, it is possible to control a difference in an electric potential between a peripheral portion and an inner portion in the substrate 1. Thus, it is possible to maintain a uniform current distribution.

The cathode electrode in a portion provided in contact with an insert ring is ring-shaped. An end of the mesh-like cathode electrode shown in Fig. 11 is connected to the ring-shaped cathode electrode. Consequently, it is possible to form the cathode electrode according to the present embodiment.

By employing the cathode electrode taking such a shape as to correspond to the chip pattern formed in the substrate 1 for the plating apparatus according to the present embodiment and thus carrying out plating, accordingly, it is possible to form a uniform plated film in the substrate 1.

While the invention has been shown and described in detail, the foregoing description is in all aspects illustrative and not restrictive. It is therefore understood that numerous modifications and variations can be devised without departing from the scope of the invention.